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Resistance to powdery mildew and barley yellow dwarf in perennial Triticeae species

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Summary

In a collaborative effort between the USDA-ARS and CAAS, 50 accessions each of perennial Triticeae held at the Forage and Range Research Laboratory, Logan, Utah, U.S.A. and the Institute of Crop Germplasm Resources, Beijing, People's Republic of China were exchanged. Eighty six and 85 accessions of these germplasms were screened for powdery mildew (caused by *Erysiphe graminis* DC) and barley yellow dwarf virus (BYDV) strain GPV, respectively. Fifty seven and 72 accessions had resistance to powdery mildew and BYDV, respectively. These materials are valuable genetic resources for breeding disease resistances in three of the major cereal crops – wheat, barley, and rye.

Abbreviations: BYDV – barley yellow dwarf virus; ELISA – enzyme-linked immunosorbent assay.

Introduction

Perennial Triticeae has been a rich genetic resource for wheat improvement (Cauderon, 1979). Numerous species have been hybridized with wheat (*Triticum* spp.) as well as the other two annual cereals, barley (*Hordeum vulgare* L.) and rye (*Secale cereale* L.) (Dewey, 1984; Wang, 1989a). Therefore, perennial species of the tribe Triticeae can contribute desirable characteristics to the three major cereal crops.

China is one of the major distribution centers of perennial Triticeae. There are about 100 species of perennial Triticeae grasses in China (Kuo, 1987). The USDA Living Collection of the Perennial Triticeae in Logan, Utah has about 1500 accessions of 250 native and introduced species. A collaboration between the USDA-ARS, Forage and Range Research Laboratory, Logan, and the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, Beijing, was established to evaluate the collections in the two institutes for desirable genes that are useful in cereal improvement.

Dong *et al.* (1992) reported some desirable characteristics found in Chinese perennial Triticeae. The present paper lists those accessions carrying resistance or immunity to 11 Chinese physiological races (Si et al., 1987) of powdery mildew (*Erysiphe graminis* DC) and the GPV serotype (Zhou et al., 1987) of barley yellow dwarf virus (BYDV) in both USDA and CAAS collections.

Materials and methods

One hundred accessions of perennial Triticeae (50 from the USDA collection, 50 from China) were

Table 1. Accessions in the USDA collections that are resistant or immune to powdery mildew caused by *Erysiphe graminis*, or barley yellow dwarf virus (BYDV) serotype GPV, or both

Species	Accession	2n	Origin	Powdery mildew[a]	BYDV[b]
Australopyrum					
Au. retrofractum A. Löve	PI531553	14	Australia	0	NT[c]
	Pullen-1079	14	Australia	0	NT
Elymus					
E. alatavicus (Drob.) A. Löve	PI499475	42	China	2	S-R
E. mutabilis (Drob.) Tzvelev	PI531639	28	USSR	0	S-R
E. arizonicus (Scribn. & Smith) Gould	PI531558	28	U.S.A.	0	S
E. batalinii (Krasn.) A. Löve	PI314623	42	USSR	1	S
E. breviaristatus Keng	PI531563	42	China	0	HR
E. caninus L.	PI252044	28	China	0	S-HR
E. caucasicus (C. Koch) Tzvelev	PI531572	28	USSR	0	S
E. coreanus Honda	PI531578	28	USSR	NT	R
E. fedtschenkoi Tzvelev	PI531608	28	USSR	NT	S-HR
E. fibrosus (Schrenk) Tzvelev	PI315491	28	USSR	0	S-HR
E. glaucissimus	PI314624	42	USSR	4	R
E. glaucus Buckl.	PI232263	28	U.S.A.	0	S-R
E. kengii Tzvelev	PI531619	42	China	1	S-HR
E. laxiflorus (Keng) A. Löve	PI531631	28	China	0	R-HR
E. praecaespitosus (Nevski)Tzvelev	PI314622	28	USSR	0	R-HR
E. breviaristatus ssp. *scabrifolius* (Döll) A. Löve	PI531544		Argentina	0	R-HR
E. scabriglumis (Hackel) A. Löve	PI202147		Argentina	0	R-HR
Hordeum					
H. brachyantherum Nevski	PI531764	28	U.S.A.	0	S-R
H. brachyantherum	PI531763	28	U.S.A.	0	NT
H. brevisubulatum (Trin.) Link *ssp. iranicum* von Bothmer	PI229448	42	Iran	0	NT
H. californicum Covas & Stebbins	PI531778	14	U.S.A.	0	NT
H. capense Thunb.	PI531780	28	S. Africa	0	NT
H. chilense Roem. & Schult.	PI531781	14	Argentina	0	NT
H. comosum K. Presl	PI269648		Argentina	0	NT
H. flexuosum Nees	Castelar-730	14	Argentina	NT	R
H. lechleri (Steud.) Schenk	PI531783	42	Argentina	0	R
H. parodii Covas	PI531786	42	Argentina	0	R-HR
H. procerum Nevski	PI531787	42	Argentina	0	R-HR
H. roshevitzii Bowden	PI499504	14	China	0	S-R
H. secalinum Schreber	PI531789	28	France	0	S-HR
H. stenostachys Godron	PI531791	14	Argentina	0	R
H. turkestanicum Nevski	Dushanbe	28	USSR	0	R
Lophopyrum					
L. nodosum (Nevski) A. Löve	PI531735	28	USSR	0	S-R
Pseudoroegneria					
P. strigosa ssp. *aegilopoides* (Drobov) A. Löve	PI531755	14	China	0	NT
P. tauri ssp. *libanotica* (Hackel) A. Löve	PI380650	14	Iran	0	R
P. spicata (Pursh) A. Löve	D-2838	14	U.S.A.	0	R-HR
P. stipifolia (Czern. ex Nevski) A. Löve	PI325181	14	USSR	1	R
P. cf. stipifolia	PI429787	28	USSR	0	R

Table 1 – Continued

Species	Accession	2n	Origin	Powdery mildew[a]	BYDV[b]
Psathyrostachys					
Ps. fragilis (Boiss.) Nevski	PI343192	14	Iran	0	R
Roegneria					
R. abolinii (Drob.) Nevski	PI531555	28	China	4	S-R
R. gmelinii (Ledeb.) Kitagawa	PI499605	28	China		R-HR
Secale					
S. montanum Guss.	PI440654	14	USSR	0	S
Thinopyrum					
T. bessarabicum (Savul. & Rayss) A. Löve	PI531711	14	USSR	NT	R-HR
T. caespitosum Liu & Wang	TK-669-1	28	Turkey	0	R
T. curvifolium (Lange) D. R. Dewey	PI287739	28	Spain	1	S-HR
T. elongatum (Host) D. R. Dewey	PI531719	14	France	0	S-R
T. sartorii (Boiss. & Heldr.) A. Löve	PI414667	28	Greece	0	S-R
T. scirpeum (K. Presl) D. R. Dewey	PI531750	28	Greece	0	S-R

[a]Resistance to powdery mildew was rated on a scale of 0 to 4 with 0 being immune.
[b]Reaction to BYDV was recorded as immune (I), highly resistant (HR), resistant (R), and susceptible (S).
[c]NT = Not tested.

used in the collaborative study. The 50 USDA accessions included 1 *Australopyrum*, 19 *Elymus*, 14 *Hordeum*, 1 *Lophopyrum*, 5 *Pseudoroegneria*, 1 *Psathyrostachys*, 1 *Secale*, and 6 *Thinopyrum* species. The 50 Chinese accessions consisted of 22 *Elymus* (including *Roegneria*), 2 *Agropyron*, 1 *Psathyrostachys*, 1 *Leymus*, and 2 *Hordeum* species. Most of the accessions were screened for resistance to powdery mildew (caused by *Erysiphe graminis*) and barley yellow dwarf virus.

Screenings for disease resistance were carried out at the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing. Ten plants of each accession were artificially inoculated with a mixture of 11 Chinese physiological races (Nos. 11, 15, 17, 51, 111, 115, 117, 215, 315, 411, and 415) of *Erysiphe graminis* at seedling stage. Reaction to these pathogens was rated on the 0–4 scale with 0 being immune and 4 being highly susceptible. Five plants per accession were screened for resistance to the GPV serotype of BYDV by the ELISA method (Zhou et al., 1987). Based on the virus concentrations in plants infested with virus-carrying aphids, reaction to BYDV was recorded as: immune (I) when no virus was detectable; highly resistant (HR) when amount of virus was slightly higher than uninfected wheat control; resistant (R) when virus concentration was same as that in the resistant control, *Thinopyrum intermedium* (Host) Barkworth & D. R. Dewey; and susceptible (S) when virus titer was as high as that in virus-infected wheat.

Results and discussion

Forty-five accessions of the USDA collection and 41 accessions of the Chinese collection were tested for resistance to powdery mildew. Forty accessions of the U.S. collection and forty five accessions of the Chinese collections were screened for BYDV resistance. Because of reduced germinability, some accessions did not have enough plants for one or both disease screenings.

Tables 1 and 2 list the USDA and CAAS accessions, respectively, screened for resistance or immunity to either powdery mildew or BYDV, or both. Of the 45 accessions of the U.S. collection tested for reaction to *Erysiphe graminis*, only 3 had a score of 2 or above. On the contrary, most of the Chinese materials were susceptible to powdery mildew pathogens that had evolved in China. Only 15 out of 41 Chinese accessions had a reaction type 0 or 1. Four out of the 40 U.S. accessions did not

Table 2. Accessions in the CAAS collections that are resistant or immune to powdery mildew caused by *Erysiphe graminis*, or barley yellow dwarf virus (BYDV) serotype GPV, or both

Species	Accession	2n	Origin	Powdery mildew[a]	BYDV[b]
Agropyron					
A. cristatum (L.) Gaertn.	Z 592	14	China	3	NT[c]
	Z 1052	14	China	4	S-HR
	Z 1048	14	China	NT	S-HR
A. mongolicum Keng	Z 711	14	China	NT	S
	Z 720	14	China	2	R
Elymus					
E. cylindricus (Franch.) Honda	Z 755	42	China	4	S-R
E. dahuricus Turcz.	R 28	42	China	3	I
	Z 599	42	China	4	R
	Z 567	42	China	NT	I
	Z 570	42	China	0	HR
E. excelsus Turcz.	Z 885	42	China	2	HR
E. shandongensis B. Salomon	Z 1014	28	China	3	R-HR
E. sibiricus L.	R 97	28	China	2	S-R
	Z 947	28	China	3	I
	Z 948	28	China	NT	R-HR
	Z 949	28	China	1	I
E. villifer C. P. Wang & H. L. Yang	Z 689	42	China	4	S
	Z 692	42	China	1	S
E. sp. (unidentified)	Z 1017	28	China	3	R-HR
	Z 649	42	China	0	HR
	Z 947	42	China	3	I
Hordeum					
H. brevisubulatum (Trin.) Link	Z 612	28	China	1	I
H. violaceum Boiss. & Hohennacker	Z 608	14	China	3	I
	Z 614	14	China	0	I
	Z 647	14	China	0	I
	Z 718	14	China	NT	NT
Leymus					
L. angustus (Trin.) Pilger	R 77	28	China	2	S-R
Psathyrostachys					
Ps. juncea (Fisch.) Nevski	R 8	14	China	4	HR
Roegneria					
R. alashanica Keng	Z 1081	28	China	NT	NT
R. amurensis (Drob.) Nevski	Z 767	28	China	4	S
R. barbicalla Ohwi	Z 995	28	China	0	S-R
R. ciliaris (Trin.) Nevski	Z 826	28	China	3	S
	Z 1010	28	China	2	HR
	Z 1013	28	China	4	S-HR
E. ciliaris	Z 1020	28	China	3	S-R
R. confusa (Roshev.) Nevski	Z 958	28	China	NT	NT
R. gmelinii (Ledeb.) Kitagawa	Z 726	28	China	4	S
	Z 772	28	China	3	S
	Z 895	28	China	3	S
R. hondae Kitagawa	Z 684	28	China	1	S
R. nakaii Kitagawa	Z 741	28	China	3	R
	Z 781	28	China	NT	R-HR
	Z 801	28	China	0	R-HR

Table 2 – Continued

Species	Accession	2n	Origin	Powdery mildew[c]	BYDV[b]
R. pendulina Nevski	Z 723	28	China	4	S-HR
	Z 997	28	China	0	HR
	Z 993	28	China	0	NT
R. sinica Keng	Z 960	28	China	0	HR
R. tibeticus (Meld.) H. L. Yang	Z 727	28	China	4	S-R
R. tsukushensis (Honda) B. R. Lu Yen & J. L. Yang	R 107	42	China	1	R
R. varia Keng	Z 1094	28	China	NT	S-HR
R. sp. (unidentified)	Z 1001	42	China	0	HR

[a]Resistance to powdery mildew was rated on a scale of 0 to 4 with 0 being immune.
[b]Reaction to BYDV was recorded as immune (I), highly resistant (HR), resistant (R), and susceptible (S).
[c]NT = Not tested.

have any plants resistant to BYDV serotype GPV. Twenty accessions had no susceptible plants. Among the 45 accessions from the Chinese collection, only 9 were totally susceptible to BYDV. Eight Chinese accessions had immunity to BYDV, a level that was not found in the U.S. materials.

Cereal crops have been successfully crossed with many perennial Triticeae species (Sharma & Gill, 1983; Dewey, 1984; Wang, 1989a). However, resistance to powdery mildew has only been transfered into wheat from annual species *Triticum longissimum* (Schweinf. & Muschli in Muschli) Bowden (Ceoloni et al., 1988) and *Secale cereale* (Zeller, 1973). There appears to be a tremendous potential to utilize the resistance to powdery mildew in perennial species of the tribe Triticeae to improve annual cereal species. Numerous new sources of resistance have been identified in this study.

Comeau & Plourde (1987) reviewed the search for BYDV resistance in the tribe Triticeae. Testing 22 accessions of perennial Triticeae belonging to 17 species, Sharma et al. (1984) found 11 species resistant to BYDV strain PAV and all 17 species resistant to BYDV strain RMV. In the present study, we tested 85 accessions belonging to more than 64 species against the BYDV serotype GPV, which is not among the five major serotypes (PAV, MAV, RPV, RMV, SGV) (Conti et al., 1990). Only 13 accessions belonging to 10 species were totally susceptible to this serotype.

Wheat germplasm resistant to BYDV have been developed at Purdue University (Ohm et al., 1981) and Canberra-Beijing (CSIRO-CAAS joint project; P. Larkin & Z-Y. Xin, personal communication) with resistance derived from *Thinopyrum elongatum* (Host) D. R. Dewey and *Thinopyrum intermedium*, respectively. Both species have the E ($=J^e$) genome (Wang, 1985; Liu & Wang, 1993), thus the resistance might be conferred by the same allele. Other species, identified as having BYDV resistance or immunity in this study, and those by Sharma et al. (1984) and Comeau & Plourde (1987), may have different alleles if those species have different genome constitutions. Species having either the N genome (*Psathyrostachys* spp.) or the H genome (*Hordeum* spp.) most likely have different alleles, because these two genomes are distantly related to the E (or J) and S genomes (Wang, 1989b). Although *Leymus* species have BYDV resistance (Comeau & Plourde, 1987), it may be easier to use the diploid *Psathyrostachys* species if resistance gene(s) in *Leymus* is(are) located in N-genome chromosome(s). *Psathyrostachys juncea* (Fisch.) Nevski, *Ps. huashanica* Keng, and *Ps. fragilis* (Boiss.) Nevski have all been crossed with *T. aestivum* L. em. Thell. (Chen et al., 1988; Plourde et al., 1990; C. Yen, personal communication; P. P. Jauhar, personal communication). The deployment of different resistant gene(s) may provide additional protection against various strains of BYDV.

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